Dynamic Curtailment – Flexible Interconnection Technical Lessons Learned

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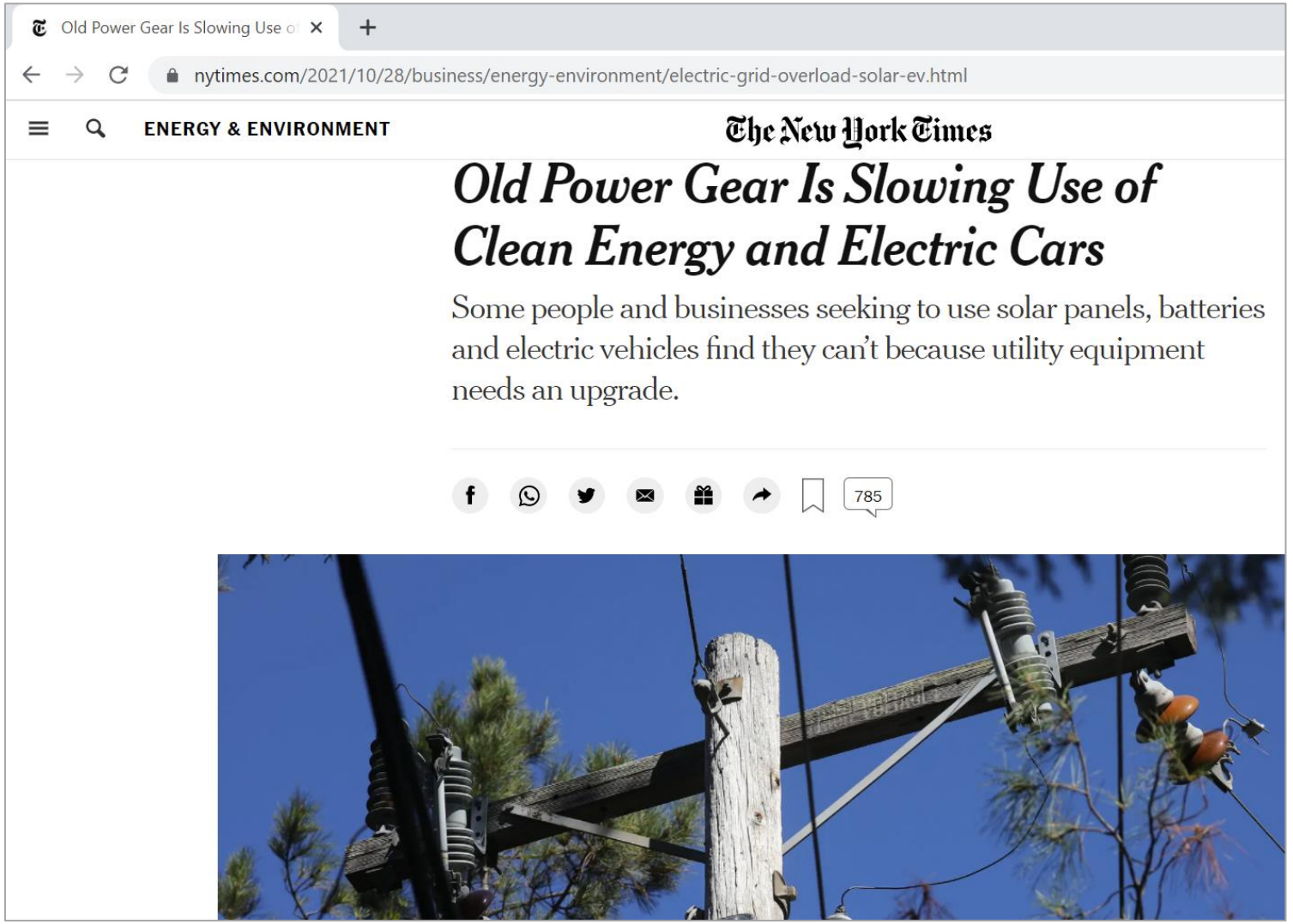
Powering the Solar+ Decade

When typical interconnection fails…

- **Cost prohibitive upgrades?** Have you experienced trying to interconnect a solar / wind / storage / fast EV charger and the costs are uneconomic and well beyond your prior experience?
- **Downsize?** Have you had to downsize that project to make the interconnection costs work?
- **Walk away from the project?** Cannot pencil out the costs? The utility says there just is not any headroom?
- **Closed feeder?** Utility says that feeder is closed to any more resources?



https://www.nytimes.com/2021/10/28/business/energy-environment/electric-grid-overload-solar-ev.html

What does interconnection innovation look like?

- Our industry rightly so focuses so much attention on how to streamline and improve solar and wind interconnection. Examples:
  - If only we would have online portals!
  - Embrace holistic process and planning solutions: e.g. no more physical signatures/payments!; systematically allow pre-applications!
- These are important. These are very important – essential. They represent lots of short-term solutions. Lots of "Faster and Better" transactional solutions
- But the solar industry needs utility approval to interconnect
- And examples of this process failing are increasing
- Are we missing something?

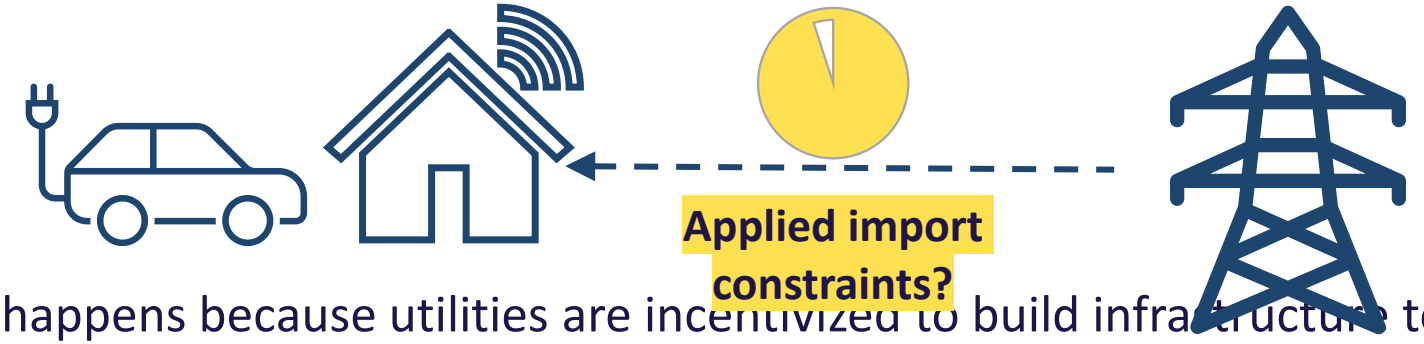
Thinking about interconnection innovation actually helps looking first at load!

- Many new loads today are smart – we can control them from our phones and computers.
- How are we using these smart loads to mitigate expensive grid upgrades?
- Are utilities best incentivized to help us control smart loads so that it saves us money and saves on grid costs?
- Do we need utility approval to connect new load to the grid? Why and why not?

- Turns out most load today is interconnected with a “connect and manage” relationship!
- Strict import constraints are exceptionally rare.

Innovative controllable load interconnection?

- We could have interconnection approval for new load.
- What would this look like?
- We try to incentivize this behavior, for instance through time-of-use (TOU) rates.
- But strict import constraints[1,2] are exceptionally rare.
- This is because import constraints are the equivalent of saying: “No utility, do not upgrade my neighborhood transformer – I will take on the risk of you not being able to serve my load.”



- This almost never happens because utilities are incentivized to build infrastructure to always reliably serve load. They get a guaranteed rate of return and socialize these electricity delivery costs on all customers.
- As noted, new load interconnects via a “connect & manage” relationship

1. https://www.nrel.gov/docs/fy19osti/70278.pdf
2. https://www.chargingfutures.com/media/1493/p1-access-options-at-transmission.pdf

Why is this so important to generation? Because Storage!

- We will need to look at import constraints for new load – new controllable charging from energy storage.
- And energy storage requires[1] interconnection, requires utility approval.
- A failure to think about interconnection for controllable load, yet requiring interconnection for generation and storage, is a failure to align incentives for consumers, generators, and utilities to find the most flexible schemes for addressing grid constraints.

- Finding innovative interconnection solutions for generation, storage, *and load* is at the center of the most affordable path to modernize our grid and decarbonize to meet our climate and social justice goals.

1. There are lots of storage loopholes. E.g. add wheels and call it a vehicle; building thermal storage & HVAC control; consumer electronics; etc. Industry needs to harmonize DER to include load.

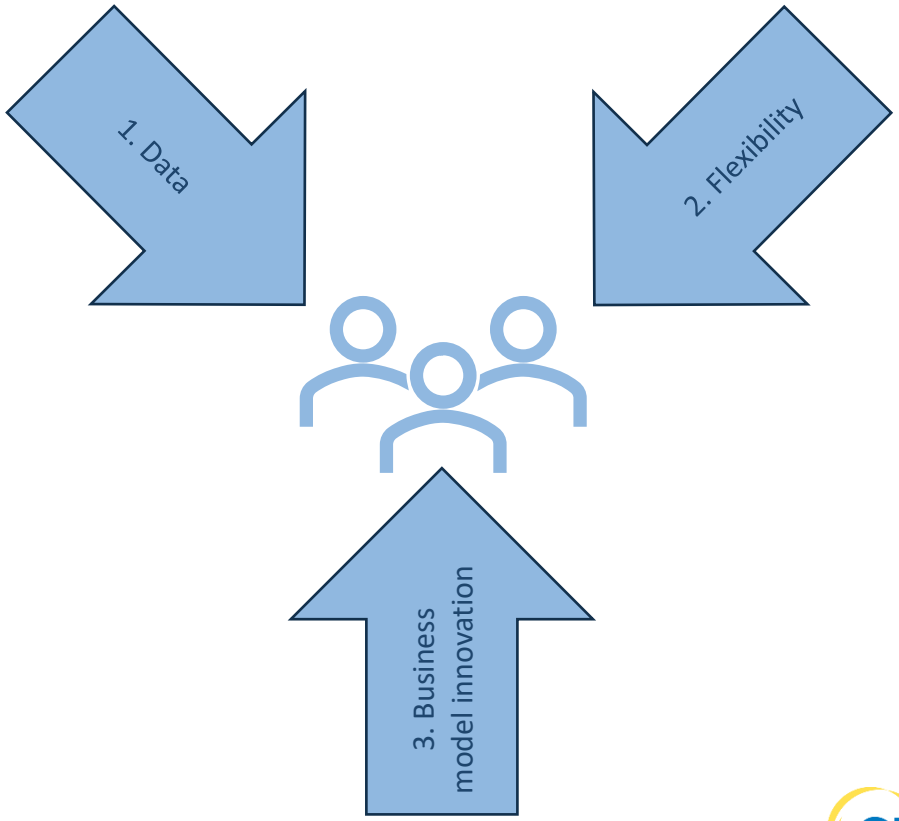
Grid modernization is both an edge and system wide-challenge

Innovations connecting generation, storage and load is inseparable with system-wide integrated resource planning.

- **Interconnection** ultimately is about *customer relationships*, yet… several concerns:
  - **Generation only?** Narrow interconnection thinking about customers seeking to change their grid use through the lens of generation.
  - **Proactive consideration of load?** Lack of consideration of changes in customer grid use for controllable load.
  - **Solutions scalable for storage?** More troubling, especially lack consideration of how energy storage is cost effective for many applications and also needs thoughtful interconnection innovations.

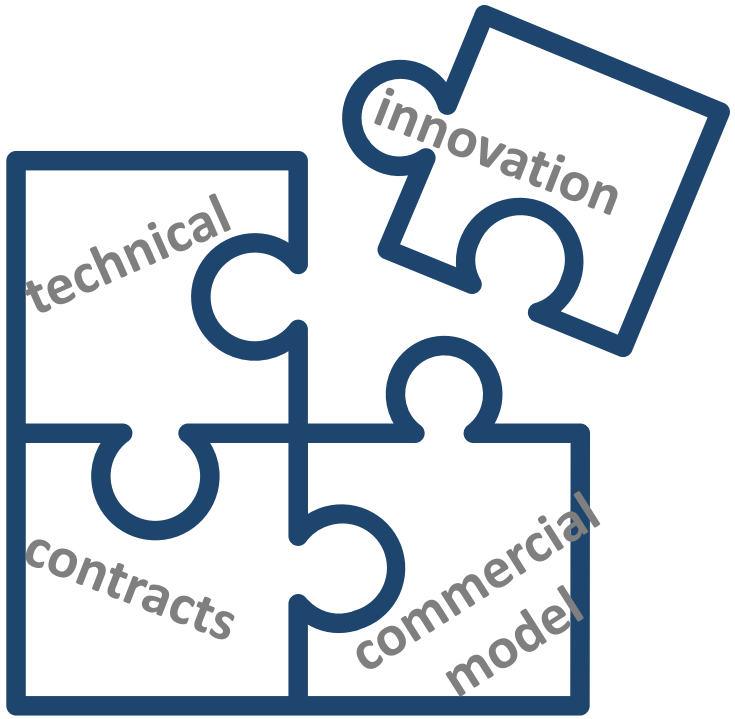
How can we connect better with customers who are seeking to change how they use the grid?

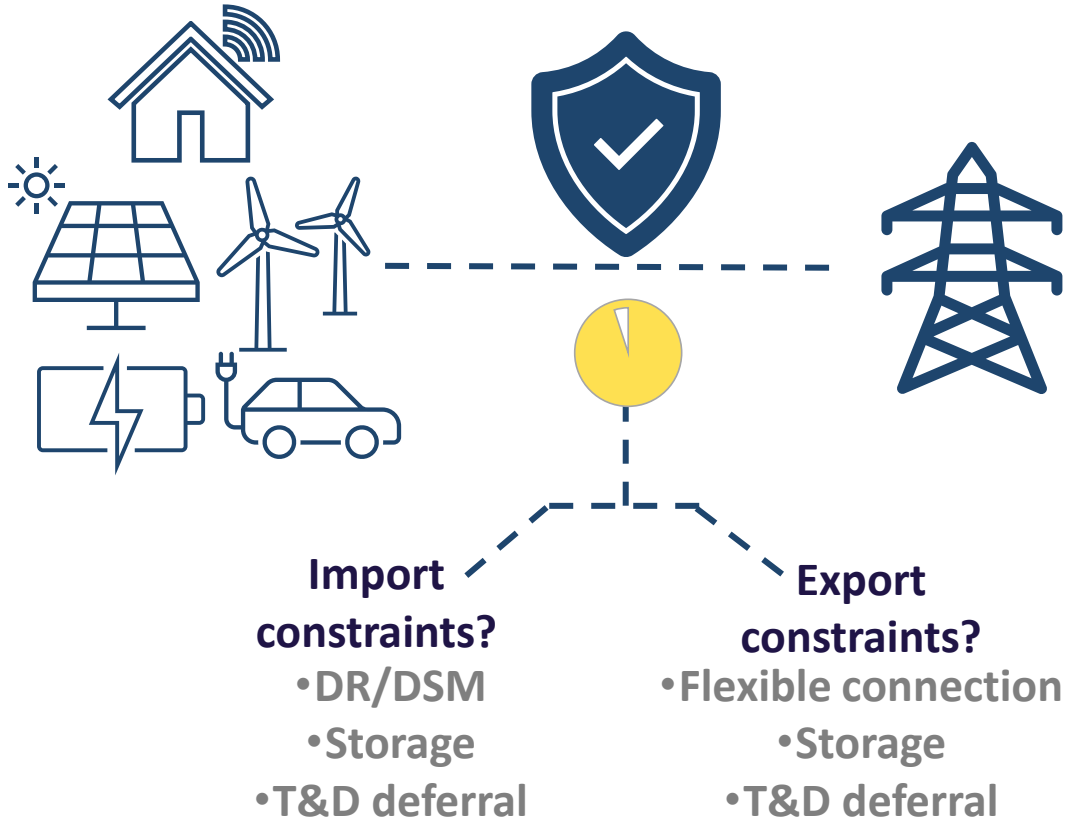
Customers should be at the heart of all grid modernization



The missing piece for holistic interconnection is intrinsic innovation in business models

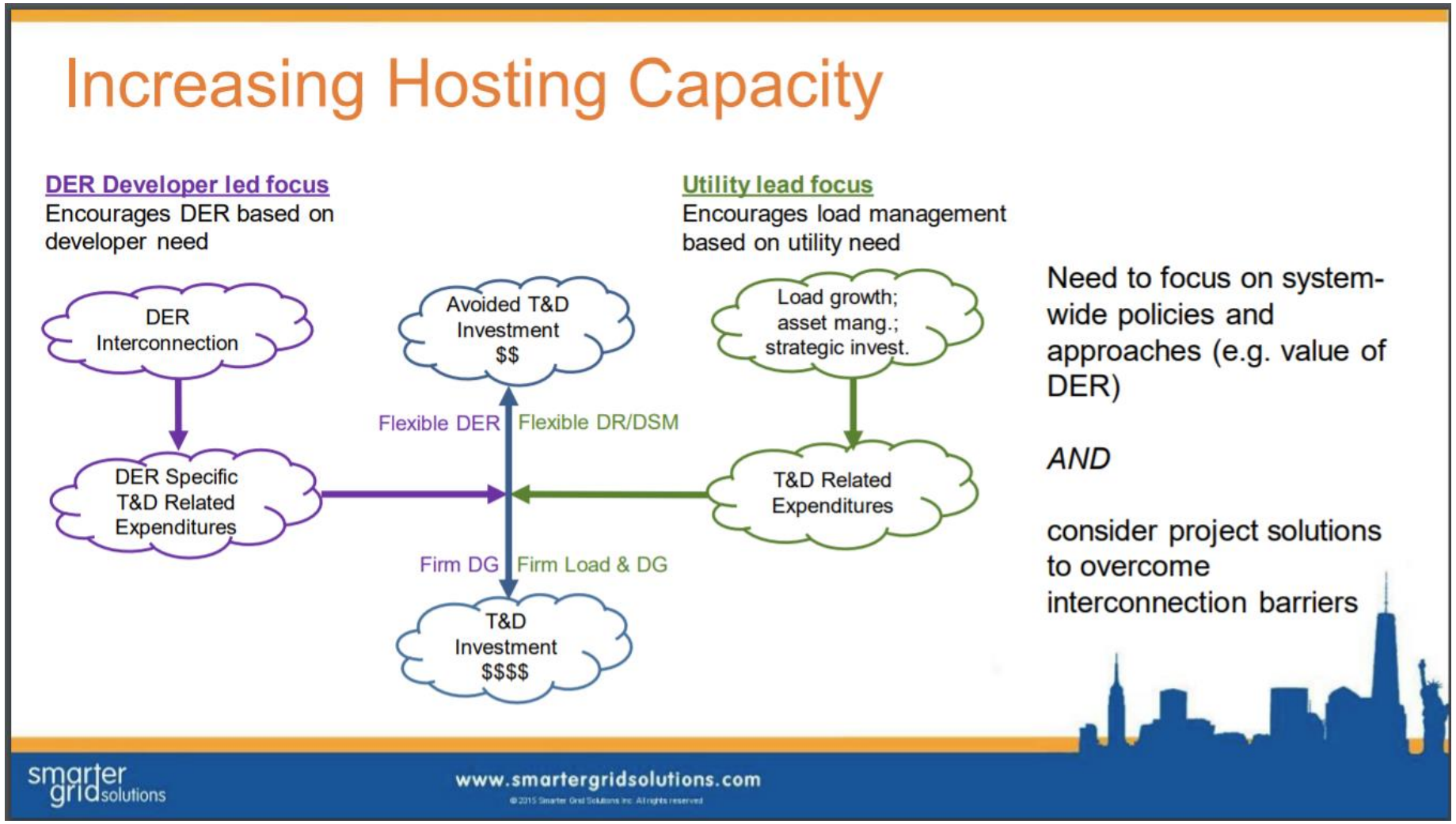
- Interconnection innovation is the missing piece to having much better customer-to-utility relationships





- Limited/No-export power control system standards address the grid edge technical requirements. Flexible interconnection adds the commercial and contractual pieces to support innovation

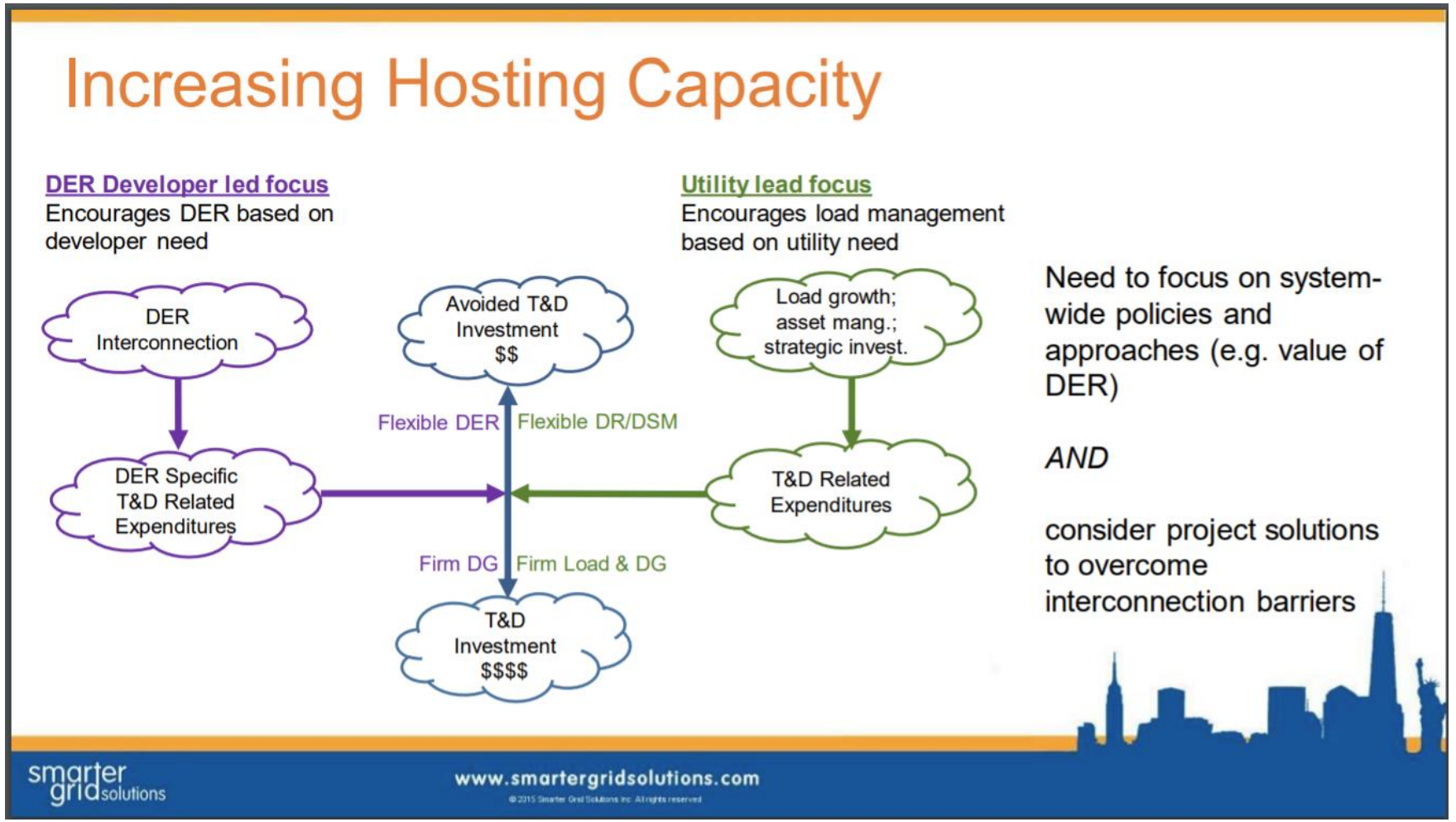
Need system wide services innovation



- **Need customer focused innovation** for new generation, storage, and load relationships but also for system wide services.
- **Grid modernization needed:** With our aging grid, but also with our electrification of heat and mobility to meet our decarbonization goals, we will need traditional reinforcements.
- **Prioritize full stack flexibility:** For system wide solutions, we need customer centered full stack flexibility services procurement to be at heart of finding the most affordable solutions.

https://jointutilitiesofny.org/sites/default/files/REV-EG-Hosting-Capacity-July-2016-FINAL.pdf

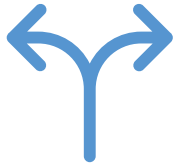
Need system wide services innovation *and* innovative interconnection relationships



- **Options:** There are a range of flexible interconnection technologies: smart inverters; storage; power system control for limited/no-export; topology switching; DERMS; etc.
- **Relationships:** Yet flexible interconnection is more than a set of technical specifications.
- **Choice:** Flexible interconnection is a customer choice compared to firm interconnection (i.e. Restricted grid use vs 100% grid use)
- **Customer rights** for choosing flexible interconnection are critical, including data rights.

https://jointutilitiesofny.org/sites/default/files/REV-EG-Hosting-Capacity-July-2016-FINAL.pdf

Acting on Customer Centered Solutions



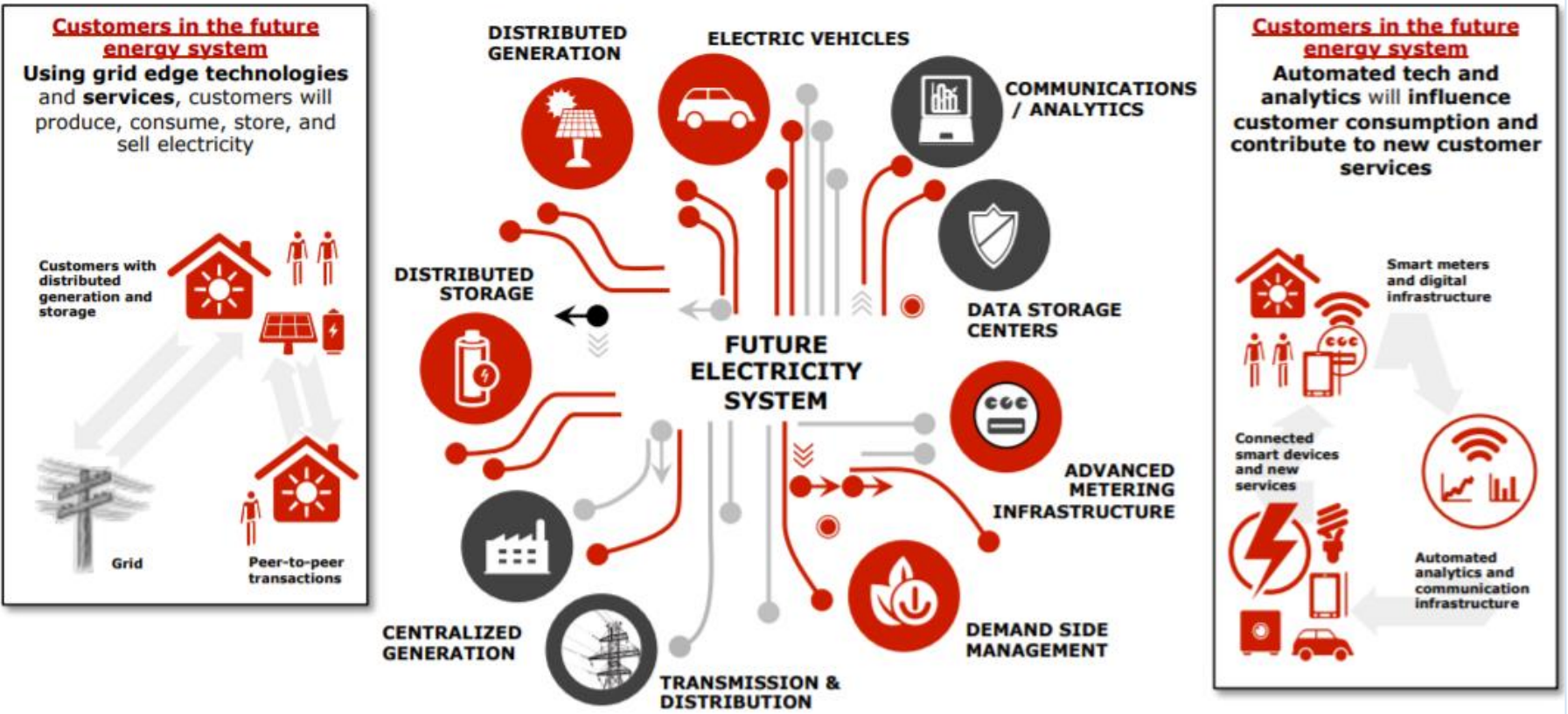
- **System-wide Solutions: Full Stack Flexibility Services – Procure as a First Priority!**
  - To mention a few, flexibility services include non-wires alternatives, smart wires and enhanced grid technologies, independent connection providers, energy efficiency and conservation, demand management, and so forth.
  - Only after finding these are insufficient should the most expensive grid upgrades be approved, and increasingly even these should be competitive. For example, community and campus microgrid solutions, offshore wind connections, new substation procurement, etc.

- **Customer Relationship Services – Prosumer Centered?**
  - Controllable load: how are you engaging customers to more provide load services to support grid modernization?
  - Generation: for connecting new generation, are you providing the full range of options to customers for the most affordable solutions grid edge investments?
  - Storage: are you considering how storage is both dispatchable generation and controllable load, and its further deployment will significantly alter how customers use the grid?

- **Protecting Vulnerable Populations to Energy Transformation Risks?**
  - Not all customers are able to fully participate in these new services, so how are you protecting vulnerable populations?

- **Analyzing competing system-wide and customer driven solutions requires DATA ACCESS!**
  - Customer rights to data during interconnection are critical to finding the most affordable grid edge solutions to modernize the grid

Data and Interconnection



World Economic Forum: https://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf

Flexible interconnection is the framework to enable dynamic hosting capacity, operationalizing dynamic curtailment

WEF 2017: "In terms of connections procedures, government-funded trials in the UK have demonstrated how to *reduce connection costs by up to 90% and connection time by about seven months*. This allows for faster and cheaper connections, supporting flexible management of energy flows and utilizing data such as real-time network hosting capacity. Success at this level requires a digitized grid with active network management."

(Emphasis added)

Better Flexible Interconnection Data Aligns to System-wide Digitalized Energy Systems

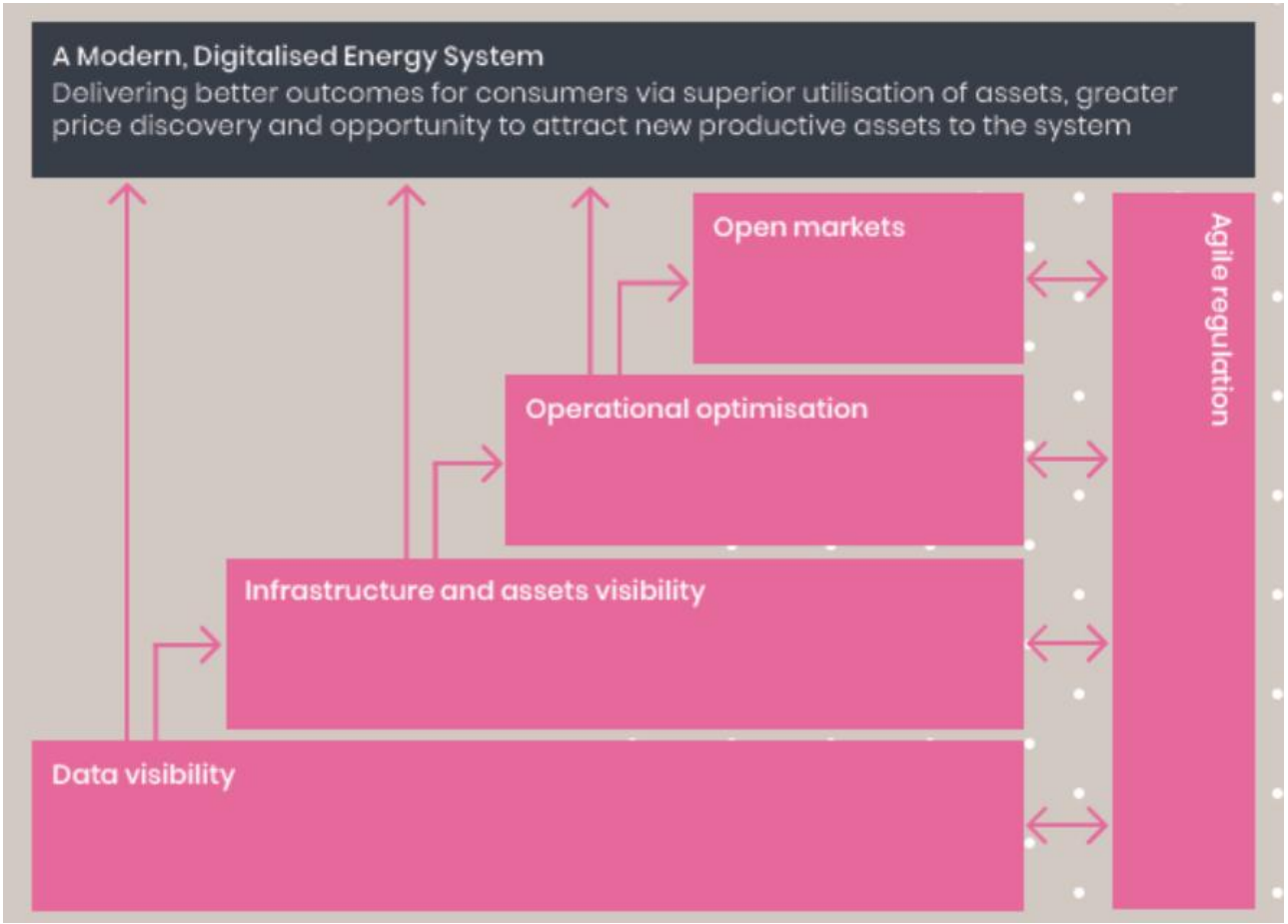
The most affordable and effective decarbonization investments need a combination of customer led and utility supported solutions.

Yet analysis is constrained by lack of data access.

And there is growing concern that digital monopolies and a range of solutions biases constrain finding the most affordable solutions.

Is industry able to analyze the most cost-effective grid modernization investments? Especially when customer solutions can defer or mitigate some?

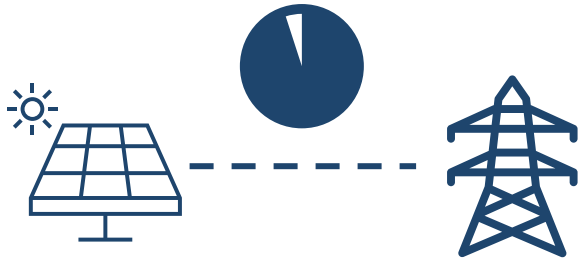
Are solar & DER customers able to analyze their most cost-effective interconnection options?



https://es.catapult.org.uk/report/energy-data-taskforce-report/

Flexible vs Firm Interconnection & Data Access

Flexible Interconnection

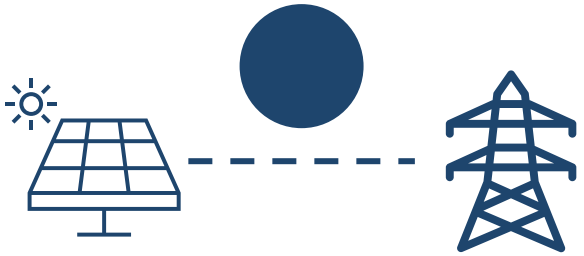


- Managed grid access during grid constraints, typically acceptable with 95-99% grid access
- Risk of curtailment provides market-based decision making for firm vs flexible interconnection; enables enhanced, dynamic hosting capacity assessments; choice is essential

DER developers & customers have the right to request grid data and the models used to analyze curtailment risks

- Can provide faster and cheaper interconnection; market-based customer relationship
- Practical pathway for future customers who may want to deploy storage

Firm Interconnection



- Firm or 100% access to the grid
- Always the best choice when grid utilization is low; lots of excess hosting capacity

Customer access to grid data necessary for long term planning horizons, like community solar or microgrid solutions

- Relies upon “static hosting capacity” that is based on snapshot, worst case conditions that are rare
- Fit and forget customer relationships

Define the Principles for Customer and System-Wide Innovations

The industry therefore needs to define the principles for acting on innovation, for grid edge interconnection of new generation, storage (and load!), *and* system-wide clean energy infrastructure investments. We therefore need:

- **Defined customer rights** that put customers at the center of grid modernization and that support their ability to make reliability and resiliency investments, leveraging their value for all customers.
- **Aligned incentives** so that monopoly operators act in the interests of all consumers. Special attention should focus on mitigation and where possible removing data and customer relationship monopolies.
- **Cost reflective** charges for monopoly services that reflect incremental costs and benefits of how consumers and other parties use the system. This includes minimizing harmful distortions arising from the recovery of fixed charges for using energy networks.
- **A level playing field** so that all technologies and business models can compete equally, without barriers to entry to the market.
- **Efficient allocation of risk** so that those best placed to manage the uncertainty inherent in a rapidly changing system shoulder the risks involved.
- **Harnessing markets and competition** where it can bring benefits to consumers.
- **Support for vulnerable communities** to address energy bill burdens and build resiliency.

Principles adapted from Ofgem, 2017

Data Access and Short-term Relationship Priorities

Customer Centered Interconnection = Customer centered grid modernization

- Proactively provide the full range of interconnection options for generation and storage (*and controllable load!*)
- **Digitize and shift to industry management of submitting and tracking interconnection applications**
- **Embrace holistic process and planning solutions: *e.g. no more physical signatures/payments!; systematically allow pre-applications!***
- **Ensure industry access to grid data for evaluating the most affordable grid modernization options**

Increase Level 1 to 15 or 20 kW - Expedite processing and reducing costs

- Pilot moving to a "connect and manage" relationship for generation, and "connect and value grid services" relationship for storage
- Move to "free the roof" relationships, allowing customers and DER developers to manage their investment risk for sizing generation and storage; support upsizing solar concurrent with EV and electrification of heat deployment incentives

Enforce Interconnection Timelines - Establish performance and service metrics, and guarantees

- Clear and explicit interconnection timelines for expeditiously processing the increasing volume of applicants

Interconnection and Grid Access Data

- **Establish grid data rights for industry due diligence studies of grid constrain management solutions for interconnecting to constrained grids; establish robust principles of access for customers to connect to constrained grids**

Interconnection Cost Certainty and Predictability

- Ensure actual system upgrade costs fall within a reasonable range (+ or - 25%) of the utilities' initial estimates
- **Provide firm vs flexible upgrade costs; ensure costumers always have both choices available and data rights to investigate**

Move Beyond the Cost-Causer Principle and Reform Cost-Allocation

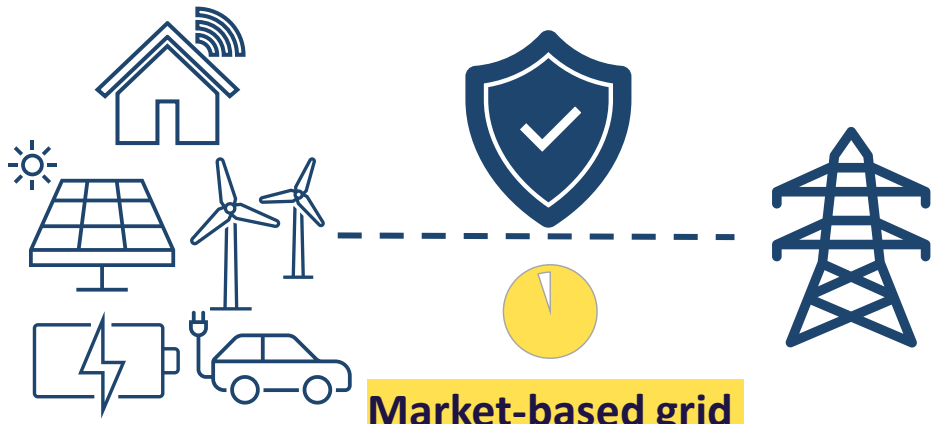
- States across the country are exploring cost allocation models where utilities can recover upgraded hosting capacity costs through the ratemaking process or a regulatory asset and interconnection customers using the upgraded capacity pay a proportional share of the costs to reduce the amounts needed to be recovered. But is this process fully providing market signals?
- Move for instance to determining reinforcement costs based on a Common Connection Charging Methodology (CCCM) that holistically considers shallow versus deep recovery for new generation, storage, *and load*.

Move Beyond Confrontation to Genuine Mutual Collaboration

- Appoint a Customer Negotiation Commission for short-term conflict resolution and establish long-term collaborative processes like those recently noted in Hawaii (https://puc.hawaii.gov/energy/pbr/)

Moving to “Connect and Manage” relationship for generation, storage and load

- We already largely use a connect and manage relationship for load.
- We need to extend “connect & manage” to generation and storage.
- We will need similar, but different customer relationship end states for interconnecting to Transmission, Distribution utility scale, and small scale BTM
- Treating new load, generation and storage must be done fairly and consistently
- **Small DG & storage lessons learned:**
  - Most residential/small business customers lack sophisticated energy insight to analyze curtailment risk
  - Better to move to “connect and notify” relationship and use improved behavior techniques to manage real-time loading
  - Shared burden & risk: 3% curtailment rule?
  - Fair for EVs, heat pumps, solar and storage?



“Connect and Manage” needs more market-based processes and full stack flexibility solutions

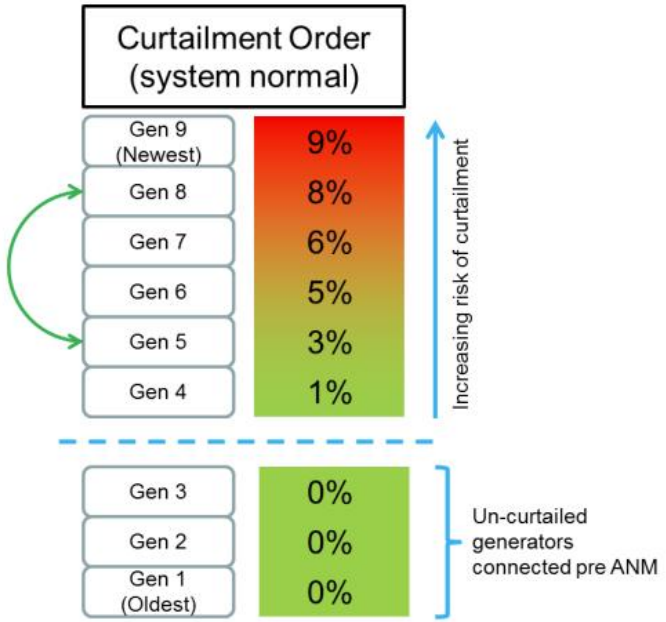
- **Large DG and FTM lessons learned:**
  - Guaranteed “connect and manage” one-month interconnection approval
  - Always provided with firm and flexible interconnection options. Utility (or their service providers) perform curtailment assessment

  - Always ensure data rights access. 3rd party due-diligence requires curtailment risk reproducibility
  - Industry should have three months to accept the offer or reject and initiate material modifications and resubmit the application.

- **Utility Scale and transmission:**
  - Same firm vs flexible interconnection framework applies; move to guaranteed “connect and manage” three-month interconnection approval
  - Can leverage energy service vs network service framework

Curtailment: One Half of Bi-directionality Markets

Figure 3: Trading between two generators that are at risk of being curtailed



- Curtailment doors should swing both ways – this is essential for affordable grid modernization
- The US needs a national standard for bi-directionality power control systems. Applicable at the key interfaces:
  - T-to-T interties (HVDC)
  - T-to-flexIPP
  - T-to-D
  - D-to-flexDG (FTM)
  - D-to-flexDER (BTM)
- And we need to look holistically at market processes
  - Tradable curtailment rights?
  - Increased curtailment risk triggering cluster upgrade and market-based cost allocation?

https://www.chargingfutures.com/media/1396/product-1-and-product-2-combined-report_version-10.pdf

Gen & Storage Flexible Interconnection Policy Priorities

- **Small DG and Storage** – transition asap to connect and notify
- Intermediate policy solutions need to ensure storage, generation and load are treated fairly in interconnection management
- **Larger generation and storage priorities today?**
  - Interconnection is contractual, and contracts today already typically include system contingency curtailment risk
  - Tweak contracts to include flexible interconnection and curtailment risk; *no significant policy change needed*
  - Ensure developers always have firm vs flexible interconnection choice, and curtailment risk is provided
  - Ensure developers always have data access rights to self assess curtailment risk
  - Apply performance-based governance to interconnection studies and queues.
    - Carrots and sticks
    - Set a target date of 6 months to halve interconnection study and approval times
- Look holistically at data access opportunities for interconnection and system-wide optimization

Q&A Reference Material

Access rights are built upon several choices

Figure 1 – Access rights are a combination of different access choices

Firmness of rights This is the extent to which a user's access to the network can be restricted (physical firmness) and their eligibility for compensation (financial firmness) if it is restricted.

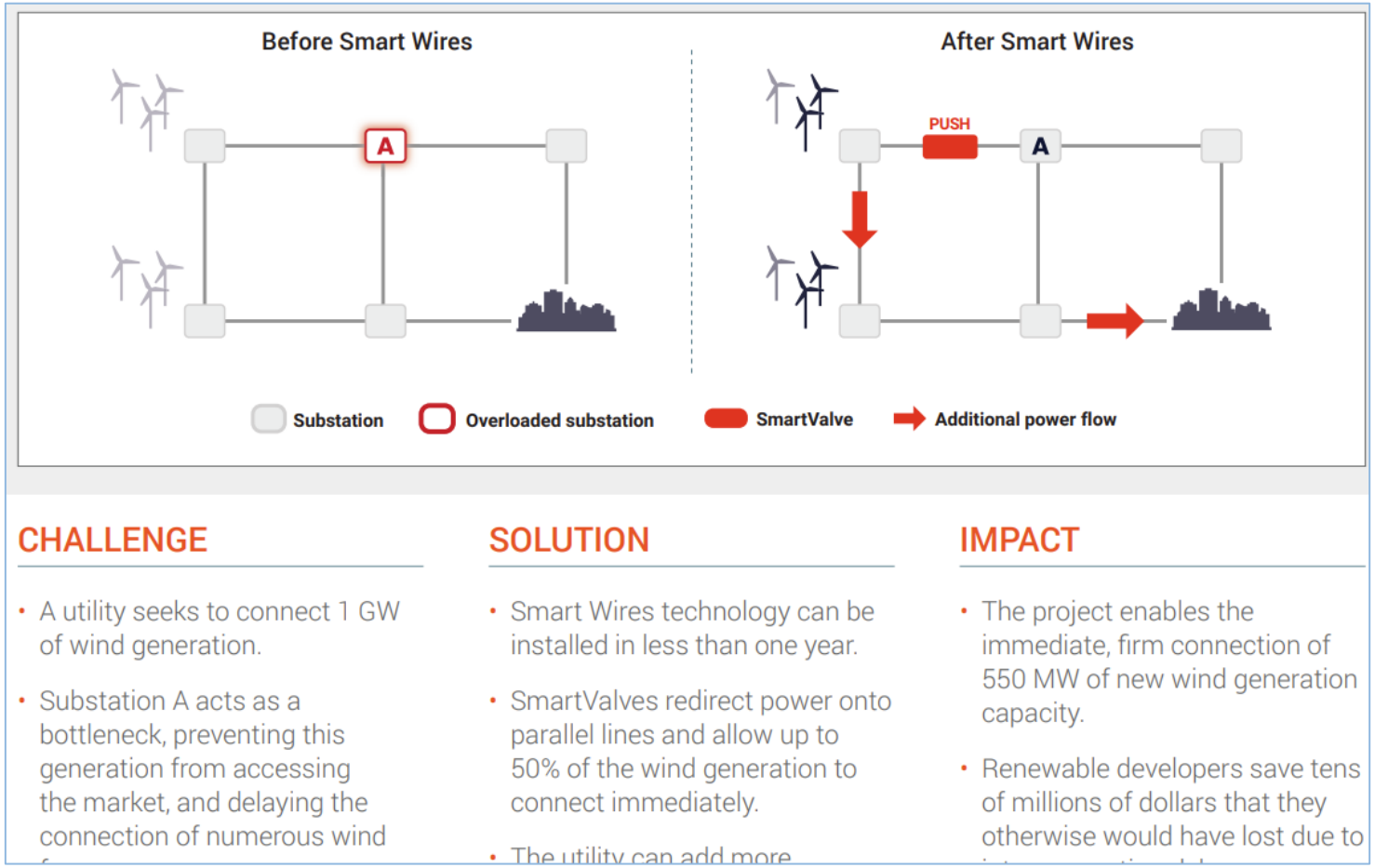
Time-profiled rights This would provide choices other than continuous, year-round access rights (eg 'peak' or 'off-peak' access).

Shared access rights Users across multiple sites in the same broad area obtain access to the whole network, up to a jointly agreed level.

Other arrangements we are considering (1) Short term rights - This would provide a choice for limited duration access (eg one year) where long term access is not immediately available or where the user does not want to make a long-term commitment. (2) New access conditions - This could involve introducing conditions on access, for example 'use-it-or-lose-it' or 'use-it-or-sell-it'.

https://www.ofgem.gov.uk/sites/default/files/docs/2019/09/summer_2019_-_working_paper_-_access_right_note_final_nd.pdf

Flexible Interconnection: Applicable to Transmission Too



CHALLENGE

- A utility seeks to connect 1 GW of wind generation.
- Substation A acts as a bottleneck, preventing this generation from accessing the market, and delaying the connection of numerous wind

SOLUTION

- Smart Wires technology can be installed in less than one year.
- SmartValves redirect power onto parallel lines and allow up to 50% of the wind generation to connect immediately.
- The utility can add more

IMPACT

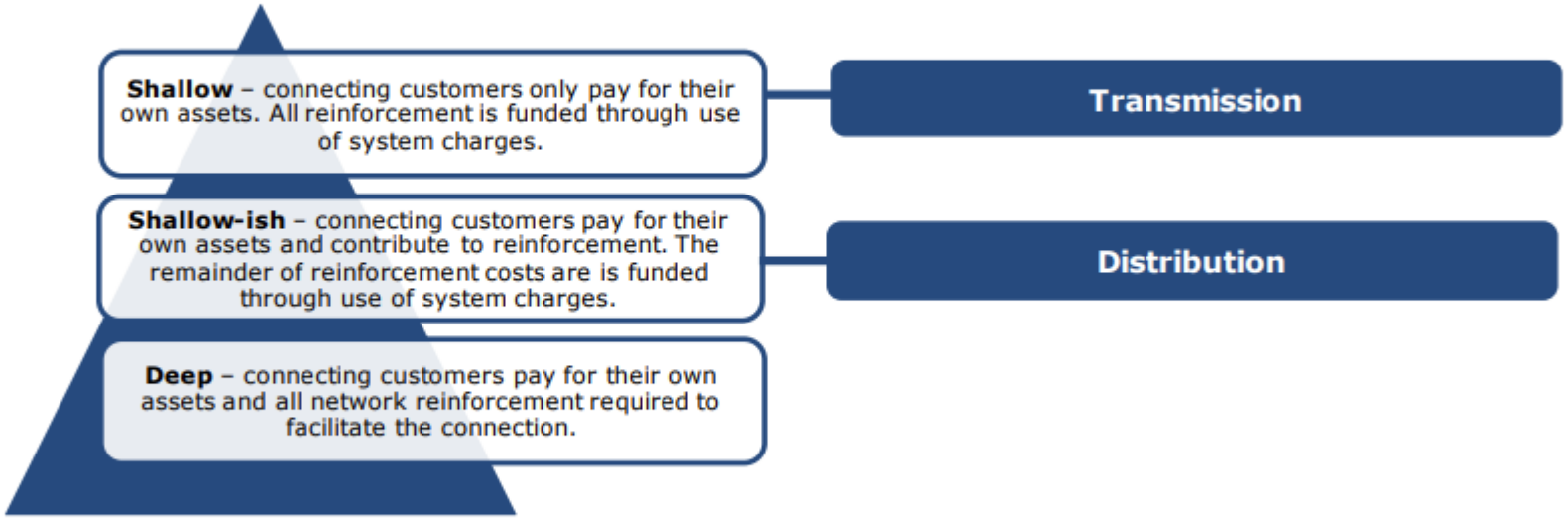
- The project enables the immediate, firm connection of 550 MW of new wind generation capacity.
- Renewable developers save tens of millions of dollars that they otherwise would have lost due to

https://www.smartwires.com/wp-content/uploads/dlm_uploads/2019/05/NewCaseStudy-Renewable.pdf

Look holistically at cost allocation

A customer's connection charge is determined by the connection charging boundary. The connection boundary is the extent to which customers pay for their connection, including their contribution to any reinforcement that is required to facilitate their connection. Customers connecting at distribution currently face a "shallow-ish" boundary.

We are assessing the case for making the boundary more shallow for demand and or generation (including whether it should be the same for both).



We previously highlighted the strong interactions between connection and DUoS charging. Given we are delaying our decisions on DUoS, we have tested the resilience of the different connection charging options against different possible outcomes on DUOS. We think that publishing an early minded-to position on connection charging on this basis has benefits (eg, in terms of planning ahead of RIIO-ED2), rather than waiting any longer.

https://www.chargingfutures.com/media/1512/access-scr-webinar-slides-26-march-2021.pdf

Static vs Dynamic Hosting Capacity

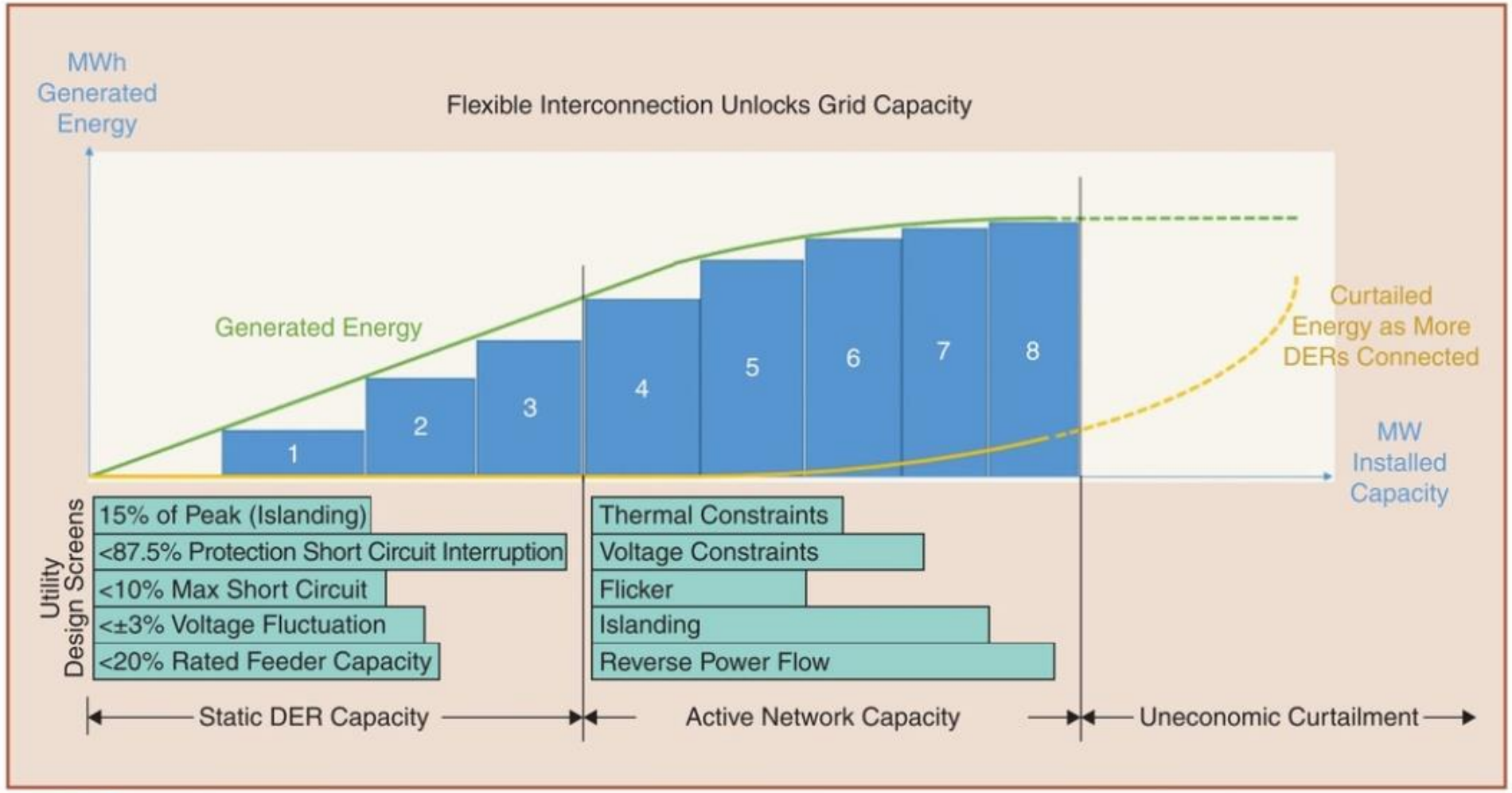


figure 1. Traditional static hosting capacity and increased dynamic hosting capacity delivered by ANM.

Curtailment: System-wide optimization

- Curtailment is very normal and typical in our industry
- Plant optimization
  - Solar is clipped as a normal part of plant design optimization. DC-AC ratio: 1.2+
- A small amount of curtailment on the grid is the same optimization, now for system-wide grid design

- Curtailment long shown to be effective in Europe:
- “Limited curtailment may be more cost effective than upgrading grid infrastructure. Curtailment of distributed generation (or “DG shedding”) has the potential to considerably increase the connection capacity and therefore accelerate the deployment of wind and solar power. **According to a study from the German distribution company, EWE Netz, the dynamic curtailment of 5% of the energy generated from solar PV increases the grid connection capacity by around 225%** without new grid investment (EWE Netz, 2015). While this might sound surprising for project developers, curtailment can lower the overall cost and accelerate the deployment of wind and solar PV.”

Source: IEA, 2016. Re-powering Markets: Market design and regulation during the transition to low-carbon power systems